

Broadband Acoustic Clutter

Charles W. Holland
The Pennsylvania State University
Applied Research Laboratory
P.O. Box 30, State College, PA 16804-0030
phone: (814) 865-1724 fax (814) 863-8783 email: holland-cw@psu.edu

Grant Number: N00014-02-1-0723

LONG TERM GOALS

The long term goal associated with this project is to improve performance of low-mid frequency active sonar systems against clutter

OBJECTIVES

The objectives are to understand the mechanisms that lead to clutter and develop models that predict the temporal/spatial/frequency dependence of the observed clutter.

APPROACH

The experimental approach is based upon exploiting both long-range observations of clutter and short-range, or direct-path observations (both seabed scattering and reflection) of the features that give rise to the clutter. Direct path observations offer two significant advantages: a) the uncertainties associated with propagation (through a generally sparsely sampled ocean) are minimized, and b) the measurement geometries are favorable to producing data from which hypotheses about the scattering mechanisms can be directly tested. The theoretical approach was taken and advanced from energy flux methods. This project is part of the Broadband Clutter Initiative Joint Research Project (JRP) including ARL-PSU, DRDC-A, the NATO Undersea Research Centre and NRL-DC.

WORK COMPLETED

The FY07 efforts included,

- 1) development of experiment plan for the Clutter07 Experiment in the Straits of Sicily in collaboration with JRP partners.
- 2) Participation in and contribution to the Clutter07 Experiment (May 9-31, 2007)
- 3) Analysis of broadband clutter from several classes of seabed features
- 4) Development of geoacoustic inversion approaches to obtain quantitative sediment properties required for modeling reverberation and clutter

| Report Documentation Page | | | | Form Approved OMB No. 0704-0188 | |
|--|------------------------------------|-------------------------------------|---|---|---------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. | | | | | |
| 1. REPORT DATE 30 SEP 2007 | | 2. REPORT TYPE Annual | | 3. DATES COVERED 00-00-2007 to 00-00-2007 | |
| 4. TITLE AND SUBTITLE Broadband Acoustic Clutter | | | | 5a. CONTRACT NUMBER | |
| | | | | 5b. GRANT NUMBER | |
| | | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) | | | | 5d. PROJECT NUMBER | |
| | | | | 5e. TASK NUMBER | |
| | | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) The Pennsylvania State University, Applied Research Laboratory, P.O. Box 30,, State College, PA, 16804 | | | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited | | | | | |
| 13. SUPPLEMENTARY NOTES code 1 only | | | | | |
| 14. ABSTRACT | | | | | |
| 15. SUBJECT TERMS | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT Same as Report (SAR) | 18. NUMBER OF PAGES 7 | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | | | |

5) Participation in the Problem Definition Committee for the ONR-PMW-180 Reverberation Workshop I and the workshop itself (including model results for test cases). Also, participation in the Data Definition Committee for the ONR-PMW-180 Reverberation Workshop II

RESULTS

An example result from the Clutter07 experiment

The measurements included long-range monostatic and bistatic observations of clutter. Also short-range detailed measurements intended to determine and quantify the scattering mechanisms associated with the clutter. There were several new wide-angle seabed reflection measurement approaches developed; data appear to be of very high quality for both kinds:

- 1) measurements using an *AUV and fixed sonobuoy*. These measurements were done at a location where we have prior data in order to compare both raw data and the geoacoustic inversion results with our standard (towed source) method. The AUV method has a tremendous potential for sampling fine-scale seabed spatial variability which is especially important for clutter features which may be of order 10-100 m in lateral dimension. Given the apparent success of the measurements, we envision extensive use of this technique in future experiments, invaluable for both quantifying geoacoustic properties of clutter objects and for all studies where knowledge of seabed geoacoustic spatial heterogeneity is important.
- 2) measurements collected with a *towed source and a drifting sonobuoy*. The drifting sonobuoy technique opens the door for measuring the seabed reflection coefficient over multiple sites without the requirement for redeployment of the receiver – this at the cost of not being able to have control (other than wind/current forecasts) of where the receiver will drift. Multiple receivers in an area could be a useful strategy but was not attempted here.

Preliminary results are discussed here that show how these measurements can be exploited to test or reject various hypotheses about seabed mechanisms driving clutter. Previous reverberation measurements (Mark Prior, NURC) indicated a high clutter area in an area that was ostensibly flat and featureless. A subsequent seismic reflection survey in 2006 (Mark Prior, in collaboration with FWG and R/V Planet) showed that there were sub-bottom “transparent sediment lenses” in that area (see Fig 1). The hypothesis was that the transparent lenses (in particular, the boundary between the lenses and the host sediment) were responsible for the observed sonar clutter. As regarding this particular mechanism, we were interested in the Clutter07 experiment to determine if the transparent lenses were still there; seismic reflection measurements showed that they were (see Fig 1).

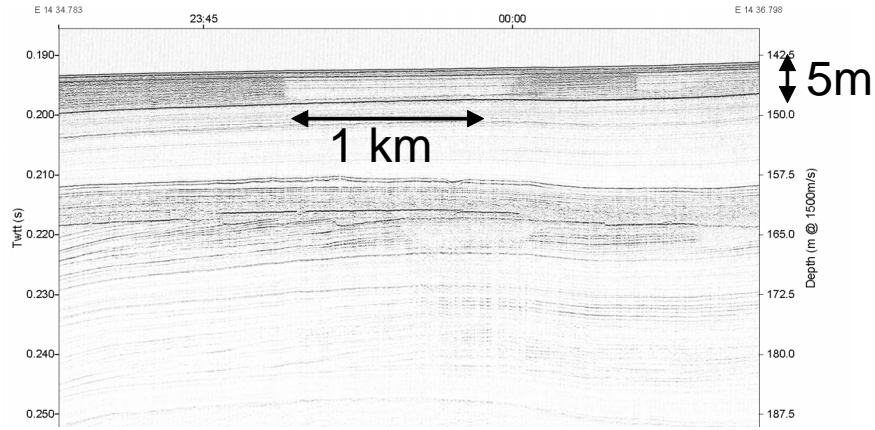


Figure 1. Seismic reflection profile collected during Clutter07 showing the “transparent lens” of dimension roughly 1 km in diameter and 5m in thickness.

The second step was to conduct wide-angle seabed reflection measurements (using drifting sonobuoys) in order to measure the geoacoustic properties both inside and outside the transparent lenses. The raw data (Fig 2) are processed to obtain layer interval sound speed and thickness estimates (see Fig 3) as well as calibrated reflection coefficients from which the full geoacoustic model is obtained via Bayesian inverse methods (work in progress).

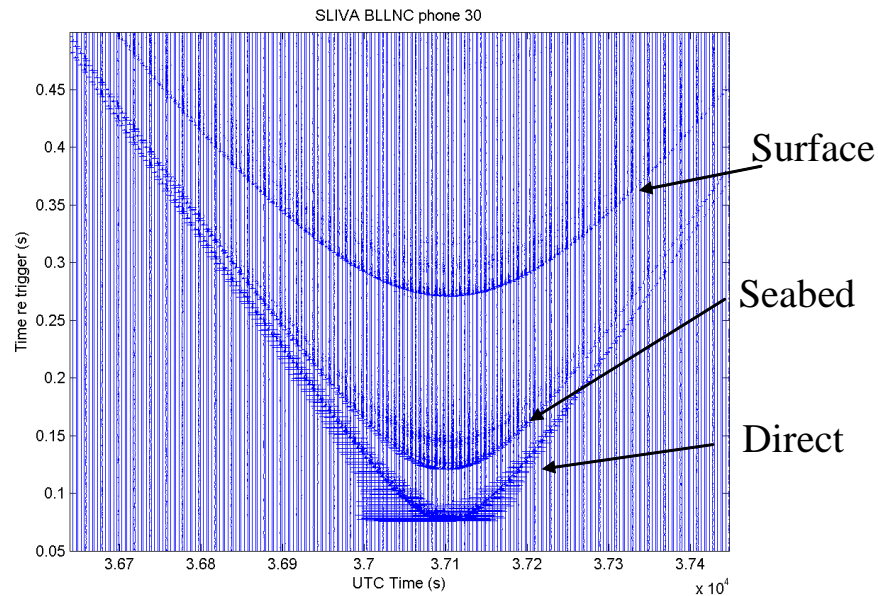


Figure 2. Raw time series data from wide angle reflection measurements directly over the transparent lens shown in Fig 1.

Inspection of the layer interval velocities (see Fig 3) shows several important aspects: first that the interval velocities inside and outside the transparent lens are the same (within the measurement uncertainties). Second, the interval velocities in the upper layer are substantially different from the 1520 m/s layer below (though very similar in normal incidence reflection behavior). This strongly suggests that the lenses themselves can not be responsible for the observed clutter, since scattering requires substantial difference in acoustic impedance at a boundary (and given the velocity similarity it is highly unlikely that the densities are significantly different). In fact, directional reverberation measurements taken nearly at the same time in Clutter07 showed no clutter at this location. The reasons for the marked difference between and “turbid” and transparent lens reflection at normal incidence is not understood at this time. Work is ongoing to address this and to understand the temporal variability and underlying mechanisms responsible for the clutter observed in 2004. One of the current hypotheses is that the processes that control the lens formation may be related to gas and that this may either directly (e.g., bubbles in the water) or indirectly (via food chain to biologics) lead to sonar clutter but on time scales related to the ebullition.

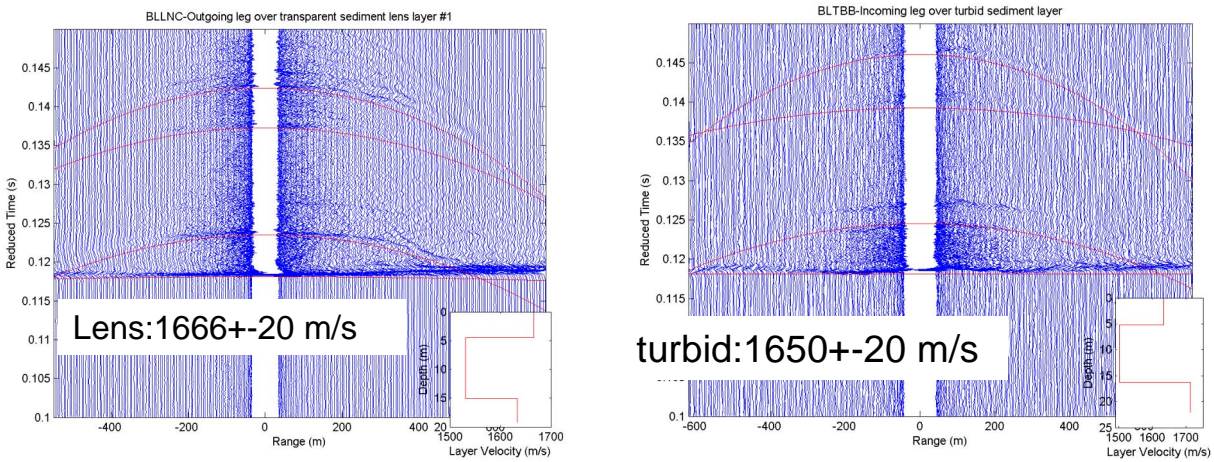


Figure 3. Sub-bottom arrivals versus source-receiver offset. Plotting the data in reduced time (reducing velocity of 1513 m/s) effectively flattens the hyperbolic arrival shape of arrivals that have traversed a path with an interval velocity equal to the reducing velocity. The water-sediment interface arrival is at ~0.118 sec, and the sub-bottom arrivals later in time. Interval velocity vs depth estimates are made by fitting the arrival structure to a model (red lines): interval velocities from the transparent lens (left) and the background host sediment “turbid (right).

Brief summary of main results from other analyses during FY07

- Shallow water mud volcanoes have a high potential for leading to sonar clutter, having large target strengths 1-14 dB 160-1600 Hz, and strongly non-Rayleigh statistics (Ref [1]-[2])
- There is compelling evidence that the mechanism leading to clutter from the mud volcanoes studied are small (~5m high, 5m in radius) carbonate mounds on the mud volcano edifice. If the mud volcanoes are active, scattering from gas in the water column or the structure itself are other potential mechanisms ([1]-[2]).

- For mud volcanoes in the quiescent state, a distribution of a viscoelastic spheres is a reasonable model for predicting the clutter ([1]-[2]).
- Buried mud volcanoes may also lead to clutter. Analyses of reflection from a single buried mud volcano (3m sub-bottom) suggests that the bulk properties are quite similar to the surrounding sediment. This analysis was not sensitive to fine-scale features on the mud volcano (e.g., carbonate mounds) that might have substantially higher densities/velocities ([3]).
- The energy flux approach for modeling diffuse reverberation agrees very closely with a normal mode approach (Dale Ellis) for the Pekeris waveguide (sediment is treated as a halfspace). We have also compared models for the more challenging case of reverberation from a sediment layer where the scattering comes from the sub-bottom (i.e., the base of the layer). In the latter case, the normal mode result has a slight bias, due to the approximation of the mode function in the sediment as purely real ([4]) .
- Previously we had demonstrated how to exploit time domain reflection data to provide initial parameterization to geoacoustic inversion of frequency domain data. Now we have shown, using a Bayesian method, how to use prior uncertainty distributions for the geoacoustic inversion ([5]).
- Previously we have tackled Bayesian geoacoustic inversion problems from a halfspace, a single homogenous layer, a single inhomogeneous layer (gradients in density and sound speed). We are now tackling problems of multiple layers (both homogeneous and inhomogeneous). ([6-7])
- It appears that the coherence of seabed reflection may be exploited to obtain sediment geoacoustic fluctuations (roughness and/or volume heterogeneities) that are important for modeling scattering from the seabed ([8]).

IMPACT/APPLICATIONS

The importance of these results is that they provide increased understanding of the mechanisms associated with sonar clutter in shallow water. The statistical characterization of these features will lead to clutter models that can be used in signal processing algorithms to predict and then reduce the impact of clutter. Some of the techniques could have a significant impact on the survey community in terms of tools and strategies.

RELATED PROJECTS

ONR Reverberation Workshop

REFERENCES

- [1] Holland, C.W., Preston J.R., and D.A. Abraham, Long-range acoustic scattering from a shallow-water mud volcano cluster *J. Acoust. Soc. Am.*, in press.
- [2] Holland C.W., Weber T., and Etiope G., Acoustic Scattering from Mud Volcanoes and Carbonate Mounds, *J. Acoust. Soc. Am.*, 120, 3553-3565, 2006.

[3] Gerig, A., and Holland C.W., Near-specular acoustic scattering from a buried mud volcano, *J. Acoust. Soc. Am.*, in press.

[4] Holland, C.W. and Ellis, D.D., Shallow water reverberation from a sub-bottom interface: a comparison of modeling approaches, *J. Comp. Acoust.*, in review.

[5] Dettmer, J, Dosso, S.E. and Holland C.W., Uncertainty estimation in seismo-acoustic reflection travel-time inversion, *J. Acoust. Soc. Am.*, 122, 161-176, 2007.

[6] Dettmer, J, Dosso, S.E. and Holland C.W., Full-wavefield reflection coefficient inversion, *J. Acoust. Soc. Am.*, in press.

[7] Dettmer, J, Dosso, S.E. and Holland C.W., Joint time/frequency-domain inversion of reflection data for seabed geoaoustic profiles, *J. Acoust. Soc. Am.*, in review.

[8] Guillon, L. and C.W. Holland, Coherence of signals reflected by the seafloor: numerical modeling vs experimental data, *Traitement du signal* (French), in press.

PUBLICATIONS

Holland C.W., Weber T., and Etiope G., Acoustic Scattering from Mud Volcanoes and Carbonate Mounds, *J. Acoust. Soc. Am.*, 120, 3553-3565, 2006. [published, refereed]

Holland, C.W., A constrained comparison of ocean waveguide reverberation theory and observations, *J. Acoust. Soc. Am.*, 120, 1922-1931, 2006. [published, refereed]

Dettmer, J, Dosso, S.E. and Holland C.W., Uncertainty estimation in seismo-acoustic reflection travel-time inversion, *J. Acoust. Soc. Am.*, 122, 161-176, 2007. [published, refereed]

Holland, C.W., Preston J.R., and D.A. Abraham, Long-range acoustic scattering from a shallow-water mud volcano cluster *J. Acoust. Soc. Am.*, [in press, refereed]

Guillon, L. and C.W. Holland, Coherence of signals reflected by the seafloor: numerical modeling vs experimental data, *Traitement du signal* (French), [in press, refereed]

Dettmer, J, Dosso, S.E. and Holland C.W., Full-wavefield reflection coefficient inversion, *J. Acoust. Soc. Am.*, [in press, refereed].

Gerig, A., and Holland C.W., Near-specular acoustic scattering from a buried mud volcano, *J. Acoust. Soc. Am.*, [in press, refereed].

Holland, C.W. and Ellis, D.D., Shallow water reverberation from a sub-bottom interface: a comparison of modeling approaches, *J. Comp. Acoust.*, [in review, refereed].

Dettmer, J, Dosso, S.E. and Holland C.W., Joint time/frequency-domain inversion of reflection data for seabed geoaoustic profiles, *J. Acoust. Soc. Am.*, [in review, refereed].

Guillon, L., Holland, C.W., Barber, C., Cross-spectral analysis of seabed reflected signals: simulations and experimental data, Underwater Acoustics Measurements Conference, Crete, Greece, June 2007, [in press].